Optimising 3D interactive exploration of open virtual enviroments on web, using mobile devices

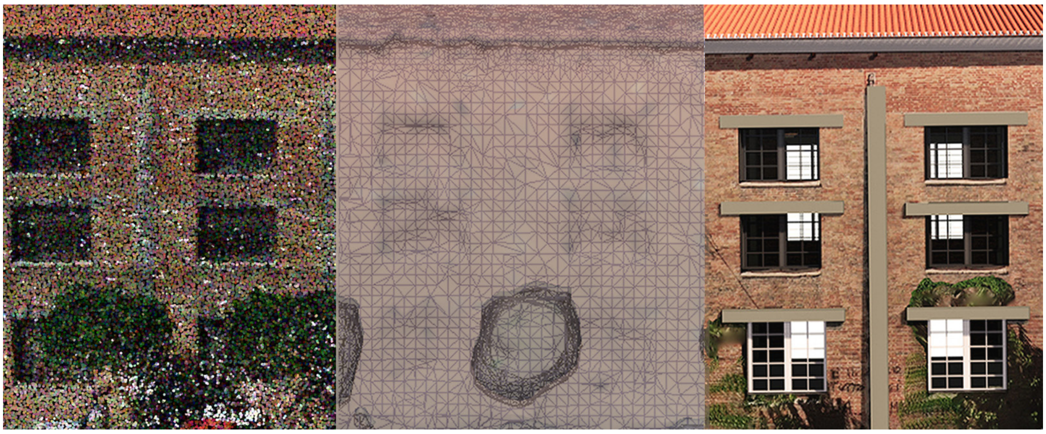
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Abstract

Thanks to the last decade's achievements with the help of digital technologies it is possible to produce high-quality replicas of cultural heritage. At the same time, the Webspace represents a great opportunity to create interactively, multi-user, immersive 3D applications for the Cultural Heritage sector that allow not only to distribute and present models, but also to interrogate them through immersive inspection and interaction tools, such as Virtual Reality experiences. However, this interesting resource introduces additional challenges in addition to common problems and limitations typically encountered in this context. Art and culture should be accessible to all, taking advantage of open platforms easily accessible to both casual users and experts in the field. Furthermore, it is necessary that any device can use the Web3D applications designated for this purpose, automatically adapting the interface, rendering and interaction models, and obtaining a single product. This paper describes a framework, evaluated through the case study, for the development of a completely free visualization mode, returning a scalable, flexible and modular solution, scanned based on the user's needs and on the object to be visualized, providing advanced functionalities in terms of 3D presentation, annotation, immersive interaction and real-time collaboration.

Parole chiave
Web3D, Cultural Heritage, real-time rendering, online content deployment, digital divide

Topics
Comprendere / condividere / svelare



Dense point cloud (left), surface polygonal model (middle) and textured BIM model (right). (Author elaboration).

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Introduction

The search for new models of communication, sharable through mobile devices, moves its first steps starting from a fundamental assumption: to believe that the enhancement of cultural heritage is not exhausted in the preservation of its materiality, but is fully realized only if the cultural heritage and its knowledge can be enjoyed and used by the community (Codice dei Beni Culturali e del paesaggio, d.lgs. 42/2004). These principles were already established in 1967 by the Franceschini Commission, when not only was the expression 'cultural heritage' introduced into the Italian legal language, but the very reason for its conservation and safeguarding was traced to its social function. This led to the establishment of the right both to information, guaranteed through prompt communication in the most suitable forms for scientific purposes, cultural knowledge, and enjoyment. Many of the numerous experiences that have characterized the segment of the applications of Information and Communication Technology (ICT) to cultural heritage can be framed in this direction, which has introduced the need for a reconsideration of the complex system of protection, management and valorization. Experiments that, in the first phase, were mainly directed towards the renovation of museums and archives [D. Rossi et al. 2018; Sylaiou, Papaioannou 2019; Wojciechowski et al. 2004], with the extension of their functions from those exclusive to conservation to those of the production and promotion of culture (fig. 01). Recording how the development of technologies and network connections has generated significant transformations in communication and fruition models, as well as in the ways of constructing knowledge, the research has moved in the wake of the most recent experiences that have expanded the notion of representation/digital model to that of the scene [Evans et al. 2014], to expand the concept of 'integrated information model', through integrations and contaminations with different environments in the directions of Webspace. As soon as the three-dimensional content has become an established multimedia content, its visualization in the Web context has become a problem [Skrodzki 2020], leading to quite limited use of it. Despite the initial difficulties, 3D content is now an eminent part of the multimedia Web experience, although there is still no standard, presumably due to the heterogeneity of the data being processed. Since the launch of the WebGL standard, the status of Web3D application development technologies has evolved steadily, with a large number of experiences produced in both software development and user-driven content production. Among the countless experiences are user groups that have focused on Cultural Heritage (CH), using high-resolution 3D models to reconstruct larger or smaller portions of the real world. 3D digital models of CH artifacts are now widespread and, in addition to their more technical uses such as documentation, restoration support, etc., are becoming very valuable in education and outreach to the general public [Anderson et al. 2010; Andreoli et al. 2018; Fanini et al. 2021; Guidazzoli et al. 2017; Osello et al. 2015]. Restricting attention to CH, a good example of commercial closed systems is SketchFab, a popular Web3D service that has given quality to its supported functionality and wide acceptance in the CH community; equally relevant is the Smithsonian Museum X3D, a tool developed by Autodesk to support the visualization of digital museum specimens [Champion, Rahaman 2020; Di Benedetto et al. 2014; Lloyd 2016]. Along with these commercial solutions, there are also several academic platforms (X3DOM, 3DHOP [15-17]) for creating interactive, high-resolution visualization web pages (fig. 02).
There are several examples of the use of 3DWeb technologies on urban heritage, such as the research PRIN 2006 'Maps, models and innovative technologies to know and share urban and environmental heritage', conducted by the University of Camerino (2007-2009), defining for this purpose an IT infrastructure that integrated different systems and open-source tools, museum collections augmented using the orientation of the device or gamified 3D experiences [Luigini et al. 2020]. The transmission of all these contents would be possible, however, if some problems of non-negligible relevance were solved: the latency before visualization should be minimized; the representation of the model should allow different levels of detail (LoD) to consider the rendering capabilities of the devices, ensuring

a reduction in the latency time before the first visualization; finally, the compression would be important to make using large 3D datasets on connections with a medium bandwidth [Boutsi et al. 2019; Lee et al. 2021; Scopigno et al. 2017; Skublewska-Paszkowska et al. 2022]. Starting from these assumptions, three main aims are pursued: one of a descriptive- knowledgeable type, defining the framework of the application fields identified, with the framing of operational protocols; another of a scientific-technological type directed at the identification of procedural protocols for the integration of 3D information levels with the web

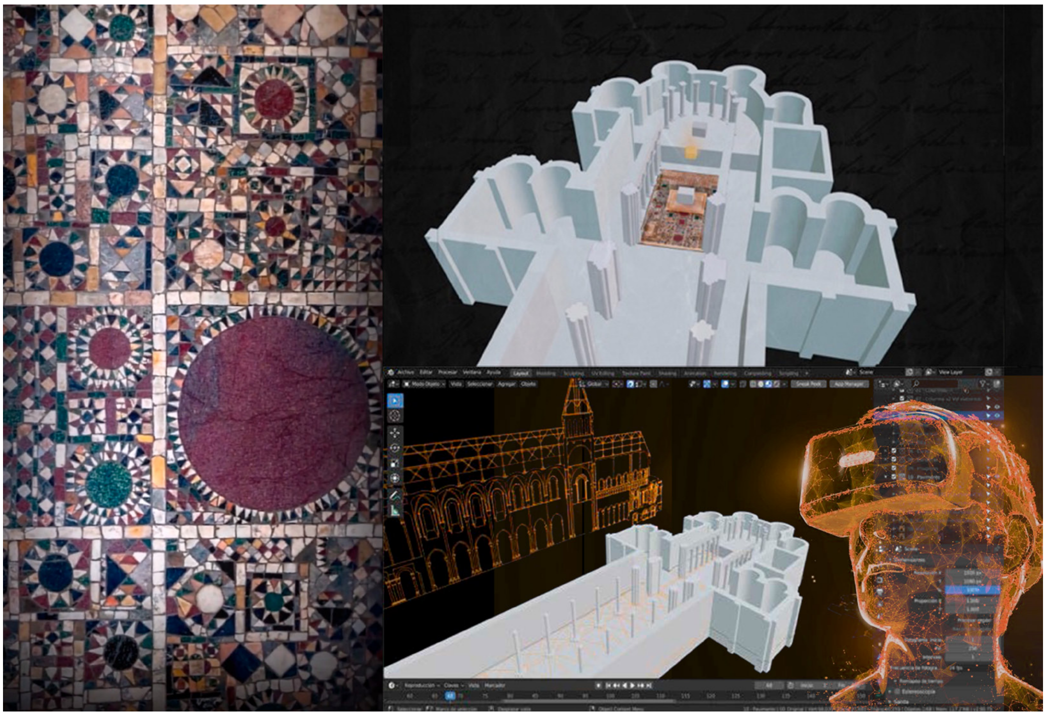


Fig. 01. An example of the use of ICT to communicate the transformations of Fleury Abbey, Saint Benoit sur Loire, France (Author elaboration).

NAME	LICENSE	TOOLBOX	SCRIPTING	MODELING	WEBVR	IMPORT
3DHOP	Open-source	Specialized tool	JavaScript	No	No	ply, nxs
Babylon.js	Open-source	3D Platform	JavaScript	No	Yes	obj, fbx, stl, gltf, babylon
Blend4web	Open-source + Commercial	3D Platform	JavaScript	No	Yes	3ds, obj, blend, fbx, ply, stl, etc.
CL3ver	Commercial	3D Platform	JavaScript	No	No	rvt, 3ds, 3dm, fbx, stl, obj, etc.
Marmoset	Commercial	3D Platform	Python	No	No	Mview/fbx, obj
Playcanvas	Open-source + Commercial	3D Platform	JavaScript	No	No	fbx, obj
Potree	Open-source	Specialized tool	JavaScript	No	Yes	las, laz
Sketchfab	Free + Commercial	Specialized tool	JavaScript	No	No	3ds, obj, blend, fbx, ply, stl, etc.
Unity	Free + Commercial	Game engine	UnityScript, C#	Yes	Yes	fbx, obj
Unity Engine 4	Free	Game engine	UnrealScript, C++	Yes	No	fbx, obj

Fig. 02. Comparison of the main Web3D tools based on WebGL technology (author elaboration).

environment and the definition of levels of interaction, participation and immersion, differentiated according to user category; finally, a strictly operational type, according to which experiments were conducted on the case study pilot with the aim of testing, validating and possibly refining the procedural and operational protocols first identified, including through the specification of Web3D platforms most suitable for the promotion and dissemination of results. We distinguish two operational keys: the first is to consider the expert user, using platforms that provide advanced features in terms of 3D presentation, annotation and immersive interaction; the second is to test new approaches aimed at knowledge, documentation, management and enhancement of cultural heritage that can facilitate access to information even to the non-expert user, through the integration and contamination of 3D models with different types of environments according to different levels of interaction.

Case study

After more than fifty years of experimentation, the themes of industrial archaeology retain significant importance because they are unexplored and increasingly linked to the strategic management of territories [Beretić et al. 2021]. The requalification of abandoned sites is insignificant in current urban policies. It is in this perspective that the proposed activity is framed. By exploiting digital tools that can be shared on the Web, it aims to involve the citizens of the town of Battipaglia, in the province of Salerno, urging them to participate in the public debate on the refunctionalization of an example of industrial archaeology, the former Tobacco Factory Farina. The complex, founded in 1920 by SAIS, Società Agricola Industriale Salernitana, is now owned by the municipality, known to be one of the most productive agricultural areas of the Sele Plain, also the main industrial center. The building that characterizes the landscape and the identity of Battipagliese today is in a state of degradation and abandonment [Guida et al. 2021]. Its favorable position, together with its unquestionable historical-architectural interest, make it a potential 'cultural container' flexible to new productive destinations (fig. 03).
In the process of administrative innovation undertaken by the public administration, the increasing space given to the participation of citizens in decision-making processes has



Fig. 03. Current state of decay and neglect (photo by author, 11/08/2021).

improved the quality of administrative action, allowing a better understanding of the context and facilitating decision-making choices. Therefore, the case study was chosen to represent the possible declinations of the 'integrated information model' concerning different environments, through different reading scales, with the consequent structuring and organization of data on mobile devices. The need for content usable through a multiplatform system has contributed to orienting the research towards web-accessible models that are free access to allow full usability by all.

Materials and methods

The designated database for application development is a dense point cloud resulting from an integrated survey. The ZEB Go is the mobile wearable laser system (WMLS) tested in the indoor environment. A 3D SLAM algorithm combines 2D laser scan data with IMU data to return accurate 3D point clouds, following the full SLAM approach implemented in the robotic operating system (ROS) library. For the outdoor acquisitions, the drone used is the DJI Mavic 2 Pro. Its camera is equipped with a 20 MP Hasselblad sensor (1'' CMOS), and a wide-angle lens with a focal length equivalent to 28 mm and FOV (Field of View) of 77°. Formalizing a schematic procedural pipeline for data acquisition and management is critical in obtaining a complete representation of the high-density point cloud structure (fig. 04). Since this application involves integrating

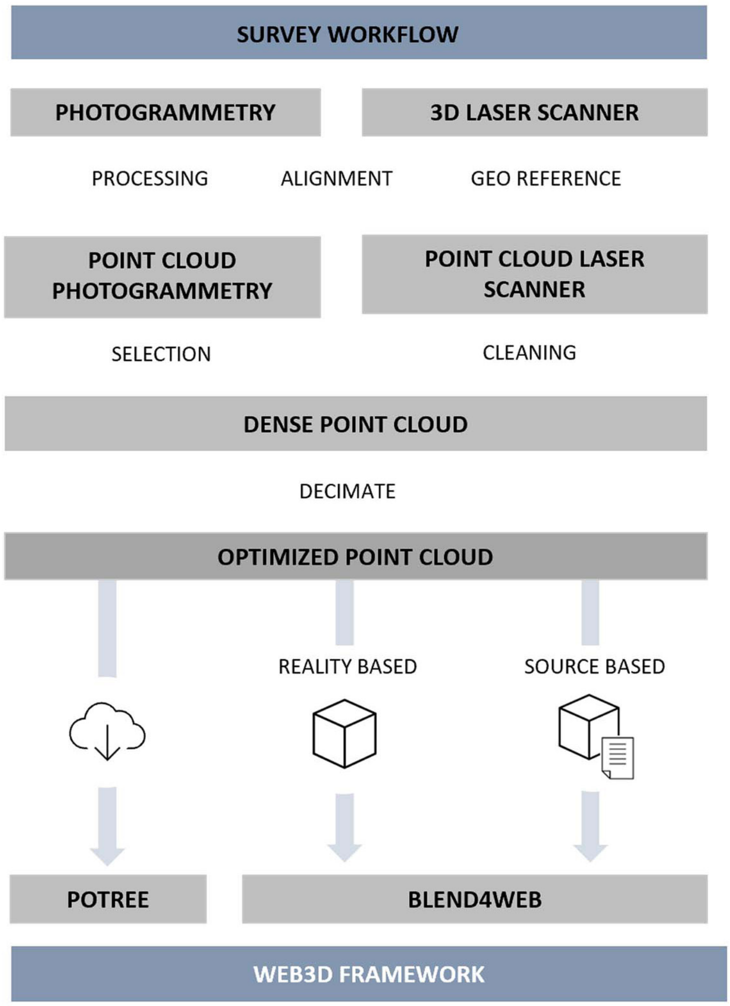


Fig. 04. Schematic workflow from cultural asset acquisition to visualization of 3D content on the Web, illustrating the most appropriate framework based on input data (author elaboration).

several techniques and technologies, both range-based and image-based [Meschini et al. 2014], to produce a complete model of the object of interest, the first step in planning the survey is to provide a reference network. To verify the quality of the final overall model, 5 ground control points (GCPs) are acquired in nRTK mode. After the acquisition phase, the scans are recorded to obtain an integrated point cloud. The extracted point cloud has more than 48 million points, with average GCPs errors of about 2.8 cm. The image and range-based clouds were imported into the CloudCompare software, also open-source, through which the registration processes (definition of a common reference system), sub-setting and sub-sampling, as well as the process of statistical outlier removal, obtained through a special filter, were performed [Isenburg 2013; Yeshwanth Kumar et al. 2019]. The resulting point cloud will be free of outliers and ready for further processing. A wide range of commercial solutions exist for web3D visualization, but they often have software dependence, presentation restrictions, and data storage, so they are ill-suited for the purpose of CH digitization that is accessible to all. Furthermore, even with the likely limitless model interactivity and full visualization customization, they are often unable to handle the common type of data used in Digital Heritage, i.e., a high polygon count 3D model. After evaluating alternatives, the choice turned to Potree and Blender4web as the appropriate framework selection for interactive 3D web presentation.

Result

In terms of storage and management from mobile devices, the criticalities that such a large database can bring have led to online platforms being developed to streamline point cloud rendering operations within web browsers. The reliability of Potree for visualizing point cloud data was tested. It is an open-source WebGL-based point cloud renderer; it is portable and efficient because it makes the point cloud viewable in any web browser, making it easy to share, distribute and publish. The final point cloud was rendered and displayed in a standard browser (fig. 05). Several tools are available for navigation, visualization in false color maps representing scalar fields (such as height) instead of true color (RGB), as well as to query the rendered model. Among these is the possibility of working with clipping-boxes, making high accuracy measurements, and extrapolating technical elaborations such as height or perspective profiles, exportable in .las format, becoming a valuable support for the drafting of technical documents by expert users in the field of AEC.

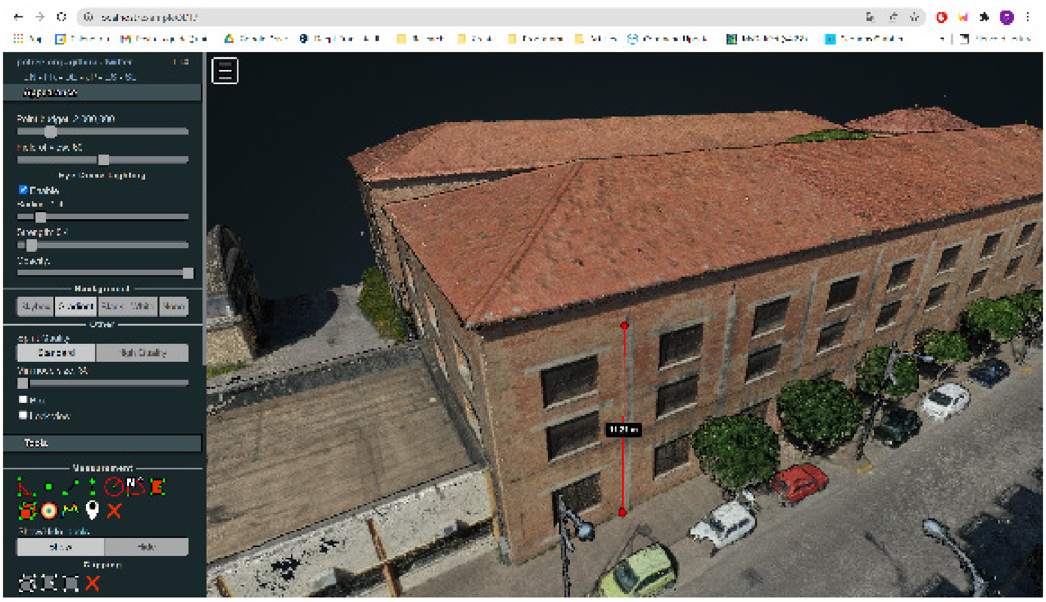


Fig. 05. Potree facilitates basic measurements on the rendered point cloud (author elaboration).

However, the Potree renderer is only capable of displaying point clouds. In many application cases, for sharing with non-technical users, point clouds are treated as raw data, intended to be refined by conversion into triangular models (the meshes) or two-dimensional images. An important element of this study is to show the potential of the meshed model created, based on the obtained point cloud.
The exported point cloud significantly impacts hardware resources, both in terms of hard disk space and RAM memory required for processing; all factors affect the possibility of developing a model manageable by mobile devices and therefore lead us to reprocess the data in different forms.
The overall point cloud has been used to create a Building Information Model (BIM), useful to systematize all the information, geometric and not, related to the complex. The model thus obtained can be imported into Blender 3.0.0, an open-source cross-platform application, and shared online through the application Blend4web ce 17.04.1, an open-source web-oriented 3D engine that integrates seamlessly into Blender as its add-on and looks like a library aimed at rendering via WebGL or other web technologies that do not require third-party software. Blender, thanks to the recent open-source openBIM extension, created by volunteers of the ifcOpenShell project, allows to read and write design files in the open IFC standard, allowing to design using Blender in the BIM standard and to cooperate with other designers working in the BIM workflow, regardless of the program used [Rossi, Palmieri 2019; Sacchi 2016]. The design in the BIM standard using Blender, unlike other BIM applications, does not use object-oriented modeling tools. The designer, using Blender functions, must create the geometry of the specified object and only in the second step adds the information layer to the geometry [Malewczyk 2021]. The BIM model of the tobacco factory, created from the point cloud exported in .rcp format and modeled in Autodesk Revit 2021, was re-exported in .ifc format and imported into Blender (fig. 06).
BlenderBIM has added access to model information: each BIM element is still associated with a classification, with additional attributes such as ifcGlobalId, ifcPredefinedType and ifcMaterial, but losing the possibility of parametric modification with the conversion to .ifc. Blender and BlenderBIM are software with very different capabilities, giving access to many different modeling methods not available in other BIM applications. Thanks to Blend4web, it is possible to share the BIM model obtained in this way to involve the general public in the public debate about the hypothesis of the tobacco factory refunctionalization, allowing a Web3d visualization on every kind of device.

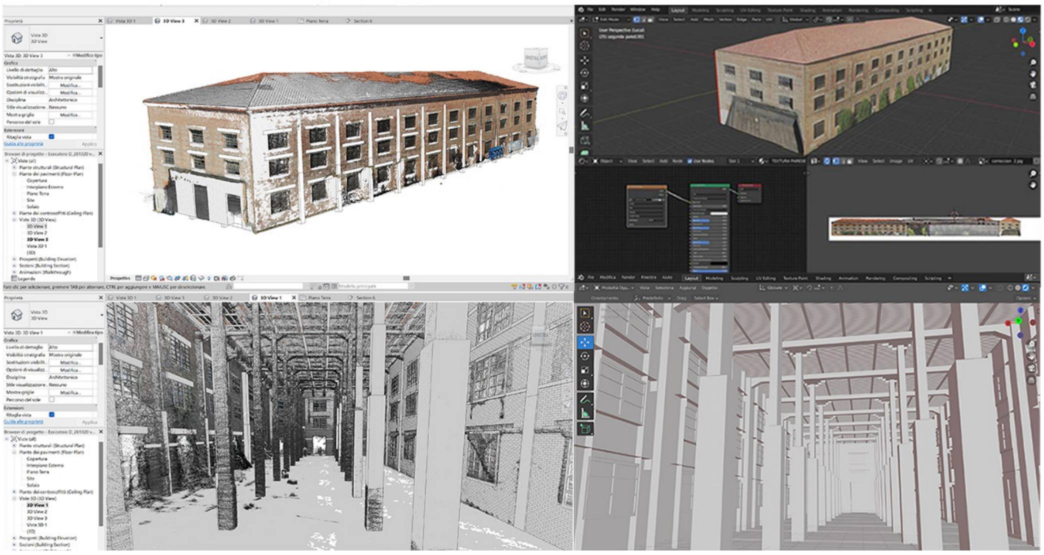


Fig. 06. From point cloud to BIM model, imported in Blender thanks to openBIM extension (author elaboration).

Conclusion

The set of proposed activities was oriented towards a reflection in the field of cultural heritage valorization, to be fully realized through the fruition of the good and its knowledge, developing the contents as a function of the user. Concerning their heterogeneity, common interfaces and display support devices, such as mobile devices, were considered, outlining a procedural pipeline for user access and interactive exploration of the 3D virtual space, where access to cultural content and the construction of structured information can be considered be achieved. The chosen case study has allowed us to represent the possible declinations of the information model through different paths and scales of reading. A parallel objective was to use open-source tools and free software in data processing and architecture, thus providing full transparency on the methodology adopted. The research has identified two critical issues. First, from the point of view of hardware, the need to have high-performance tools to ensure an immersive experience, with a sensory involvement of the user that can stimulate and enhance these new forms of communication. Unfortunately, the solutions that are touted as mobile are not entirely so. From a software point of view, there have been many difficulties in sharing content within web browsers, very flexible but resource-limited runtime environments. In addition, while representing a standard, WebGL technology is not yet well supported at the mobile level, constituting a deterrent to the development of valid applications.

References

Anderson, E. F., et al. (2010). Developing serious games for cultural heritage: a state-of-the-art review. In *Virtual Reality,* 14(4), 255–275 < https://doi.org/10.1007/s10055-010-0177-3 > (consultato il 21 marzo 2022).

Andreoli, R., et al. (2018). A Framework to Design, Develop, and Evaluate Immersive and Collaborative Serious Games in Cultural Heritage. In *Journal on Computing and Cultural Heritage*, 11(1), 1–22. < https://doi.org/10.1145/3064644 > (consultato il 12 marzo 2022).

Beretić, N., Talu, V., Cecchini, A. (2021). Emergency-Proof Tourism: The Heritage of Industrial Archaeology in Internal Areas as a Potential for a Sustainable Tourism. In *Sustainability*, 13(7), 3911. < https://doi.org/10.3390/su13073911> (consultato il 16 marzo 2022).

Boutsi, A. M., Ioannidis, C., Soile, S. (2019). INTERACTIVE ONLINE VISUALIZATION OF COMPLEX 3D GEOMETRIES. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2/W9, 173–180 < https://doi.org/10.5194/isprs-archives-XLII-2-W9-173-2019 > (consultato il 4 marzo 2022).

Champion, E., Rahaman, H. (2020). Survey of 3D digital heritage repositories and platforms. In *Virtual Archaeology Review,* 11(23), 1< https://doi.org/10.4995/var.2020.13226> (consultato il 12 marzo 2022).

Chheang, V., et al. (2017). Virtual Reality Using X3DOM. In *Journal of the Institute of Electronics and Information Engineers,* 54(1), 165–170 < https://doi.org/10.5573/ieie.2017.54.1.165 > (consultato il 2 febbraio 2022).

Di Benedetto, M., et al (2014). *Web and Mobile Visualization for Cultural Heritage*, pp. 18–35 < https://doi.org/10.1007/978-3-662-44630-0_2 > (consultato il 4 aprile 2022).

Evans, A., et al. (2014). 3D graphics on the Web: A survey. In *Computers & Graphics*, 41, 43–61 < https://doi.org/10.1016/j.cag.2014.02.002 > (consultato il 3 aprile 2022).

Fanini, B., Ferdani, D., Demetrescu, E. (2021). Temporal Lensing: An Interactive and Scalable Technique for Web3D/WebXR Applications in Cultural Heritage. In *Heritage*, 4(2), 710–724 < https://doi.org/10.3390/heritage4020040 > (consultato il 6 aprile 2022).

Guida, C. G., Di Filippo, A., D'Agostino, P. (2021). Scan-To-Bim Procedure for an Old Industrial Plant. In *New Technologies, Development and Application IV*. Cham:Springer.< https://doi.org/10.1007/978-3-030-75275-0_112 > (consultato il 13 aprile 2022).

Guidazzoli, A., et al. (2017). From 3D Web to VR historical scenarios: A cross-media digital heritage application for audience development. 2017 *23rd International Conference on Virtual System & Multimedia* (VSMM), 1–8 < https://doi.org/10.1109/VSMM.2017.8346273 > (consultato il 3 marzo 2022).

Isenburg, M. (2013). LASzip. *Photogrammetric Engineering & Remote Sensing,* 79(2), 209–217 < https://doi.org/10.14358/PERS.79.2.209 > (consultato il 12 aprile 2022).

Lee, Y., Yoo, B., Lee, S.-H. (2021). Sharing Ambient Objects Using Real-time Point Cloud Streaming in Web-based XR Remote Collaboration. *The 26th International Conference on 3D Web Technology*, 1–9. < https://doi.org/10.1145/3485444.3487642 > (consultato il 2 aprile 2022).

Lloyd, J. (2016). Contextualizing 3D Cultural Heritage. In *Conference: Euro-Mediterranean Conference* pp. 859–868 < https://doi.org/10.1007/978-3-319-48496-9_69 > (consultato il 2 marzo 2022).

Luigini, A., et al. (2020). Heritage education through serious games. A web-based proposal for primary schools to cope with distance learning. In *VITRUVIO - International Journal of Architectural Technology and Sustainability,* 5(2), 73 < https://doi.org/10.4995/vitruvio-ijats.2020.14665 > (consultato il 3 marzo 2022).

Malewczyk, M. (2021). The usage of the openBIM idea in architectural design on the example of Blender and BlenderBIM add-on. In *Architectus,* 2(66) < https://doi.org/10.37190/arc210210 > (consultato il 3 aprile 2022).

Meschini, A., et al. (2014). Point cloud-based survey for cultural heritage – An experience of integrated use of range-based and image-based technology for the San Francesco convent in Monterubbiano. In T*he International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XL–5, 413–420 < https://doi.org/10.5194/isprsarchives-XL-5-413-2014 > (consultato il 3 marzo 2022).

Osello, A., et al. (2015). *BIM and Interoperability for Cultural Heritage through ICT*, pp. 274–291 < https://doi.org/10.4018/978-1-4666-8379-2.ch008 > (consultato il 13 marzo 2022).

Potenziani, M., et al. (2015). 3DHOP: 3D Heritage Online Presenter. *Computers & Graphics*, 52, 129–141 < https://doi.org/10.1016/j.cag.2015.07.001 > (consultato il 12 marzo 2022).

Potenziani, M., Callieri, M., Scopigno, R. (2018). Developing and Maintaining aWeb 3D Viewer for the CH Community: an Evaluation of the 3DHOP Framework. In Sablating, R., Wimmer, M. (a cura di) *EUROGRAPHICS Workshop on Graphics and Cultural Heritage*. 12 – 15 novembre 2018. European Association for Computer Graphics EUROGRAPHICS TU Graz, Institut für ComputerGraphik und WissensVisualisierung CGV Fraunhofer-Institut für Graphische Datenverarbeitung IGD, Darmstadt Vienna, Austria.

Rossi, A., Palmieri, U. (2019). Lod for architectural heritage: Bim modelling for the solimene factory. *Disegno*, 2019(4), 213–224 < https://doi.org/10.26375/disegno.4.2019.20 > (consultato il 23 marzo 2022).

Rossi, D., et al. (2018). Cose dell'altro mondo. La realtà virtuale immersiva per il patrimonio culturale. In *Ambienti digitali per l'educazione all'arte e al patrimonio* [Prima ed., pp. 240–256].

Sacchi, L. (2016). Il punto sul B.I.M. In *DisegnareCON*, 9 (16).

Scopigno, R., et al. (2017). Delivering and using 3D models on the Web: Are we ready? *Virtual Archaeology Review,* 8(17), 1–9 < https://doi.org/10.4995/var.2017.6405 > (consultato il 3 aprile 2022).

Skrodzki, M. (2020). *Online Geometry Visualization Frameworks-A Case Study Generalization of two-dimensional structures View project Efficient Coordinates for Point Set Surfaces View project Online Geometry Visualization Frameworks-A Case Study Motivation.* < https://doi.org/10.13140/RG.2.2.26025.31845 > (consultato il 24 marzo 2022).

Skublewska-Paszkowska, M., et al. (2022). 3D technologies for intangible cultural heritage preservation—literature review for selected databases. In Heritage Science (Vol. 10, Issue 1). Berlino: Springer Science and Business Media Deutschland GmbH < https://doi.org/10.1186/s40494-021-00633-x > (consultato il 6 aprile 2022).

Sylaiou, S., Papaioannou, G. (2019). *ICT in the Promotion of Arts and Cultural Heritage Education in Museums*, pp. 363–370 < https://doi.org/10.1007/978-3-030-12453-3_41 > (consultato il 4 febbraio 2022).

Wojciechowski, R., et al. (2004). Building Virtual and Augmented Reality Museum exhibitions. *Proceedings of the Ninth International Conference on 3D Web Technology* - Web3D '04, 135 <https://doi.org/10.1145/985040.985060 > (consultato il 3 aprile 2022).

Yeshwanth Kumar, A., et al. (2019). Building information modelling of a multi storey building using terrestrial laser scanner and visualisation using potree: an open source point cloud renderer. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,* XLII-2/W17, 421–426 < https://doi.org/10.5194/isprs-archives-XLII-2-W17-421-2019 > (consultato il 17 aprile 2022).

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